A Study of Lanthanide-Doped Metal Oxide Nanocomposites for photocatalytic and Biomedical Applications via Green Synthesis

SYNOPSIS

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Kaajal

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Under the supervision of

Dr. Naveen Thakur

Professor

DEPARTMENT OF PHYSICS

SCHOOL OF BASIC & APPLIED SCIENCES

CAREER POINT UNIVERSITY HAMIRPUR

TIKKER (KHARWARIAN), BHORANJ

HAMIRPUR (HP)-176041, INDIA

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1. Introduction

In recent years, nanocomposites have gained immense attention due to their unique physicochemical properties and multifunctional applications. Among these, transition metal oxide such as CuO, ZnO, and CoO, MnO, have been widely studied for their photocatalytic, antimicrobial, and antioxidant properties (Ahmaruzzaman, M., 2023). However, their performance is often limited by factors such as rapid electron-hole recombination, low visible-light absorption, and moderate biological activity. Nanocomposites are hybrid materials that incorporate nano-sized particles into a bulk matrix to enhance properties beyond those of conventional composites or the individual components (Monteiro et al., 2024). The incorporation of nanoparticles typically less than 100 nm allows manipulation of matter at the molecular or atomic level, often resulting in exceptional mechanical, thermal, electrical and optical properties (Khan et al.,2022). The key benefit of nanocomposites lies in their interfacial interactions. Unlike micro-scale fillers, nanoparticles possess a high surface area to volume ratio, which provides a greater interface with the matrix material (Casati et al., 2014). These interfacial interactions often involving chemical bonding or Van der Waals forces, can dramatically improve the performance characteristics of the host material, such as increasing its strength, improving thermal resistance or enabling conductivity.

1.1 Applications of Nanocomposites

Based on their composition, nanocomposites are categorized by both the matrix material and the type of nanofiller. Matrix types include polymers, metals and ceramics. As for nanofillers, they range from nanoclays and carbon nanostructures like graphene and CNTs, to metallic and metal oxide particles, as well as lanthanide-based nanomaterials. This study focuses on nanocomposites integrated with metal oxides and rare-earth elements. These materials are of interest due to their unique and diverse functional properties. Their potential spans across catalysis, biomedical engineering and energy-related applications. (Pacheco et al., 2020).

1.2 Classification of Nanocomposites

Metal oxide nanoparticles are among the most studied nanomaterials due to their ease of synthesis, stability and diverse functional properties. Their inclusion in nanocomposites allows tuning of electrical, magnetic, catalytic and antimicrobial behaviors (Mustafa, Y. F. 2023). Copper oxide nanocomposites are formed by embedding CuO nanoparticles into a matrix material often polymers, ceramics or metals. These materials take advantage of CuO's p-type semiconducting properties, as well as its photocatalytic and antimicrobial functions. The addition of CuO enhances conductivity, enables pollutant breakdown via photocatalysis and

offers strong antibacterial potential, especially in medical applications. Common synthesis techniques include sol-gel, hydrothermal and eco-friendly green methods, ensuring effective nanoparticle integration (Al-Saeedi et al.,2021). ZnO nanocomposites are engineered by blending zinc oxide nanoparticles with base materials like polymers or ceramics. These composites benefit from ZnO's wide band gap and strong UV absorption, offering increased durability, antimicrobial action and environmental photocatalytic performance. As a result, they are extensively utilized in industries producing sunscreens, packaging materials and optical sensors (Asadpour et al., 2022). Cobalt oxide nanocomposites combine the unique properties of cobalt oxide with various matrix materials to create multifunctional systems. These composites are particularly valued for their magnetic enhancement in storage devices, high electrocatalytic efficiency in energy systems and durability under mechanical stress. They are also applied in gas detection and energy storage technologies such as supercapacitors (Li, X. et al., 2022). Manganese oxide nanocomposites are innovative materials that combine manganese oxides with other nano-sized elements like carbon nanotubes, polymers or metal oxides. Their enhanced surface area and redox capacity make them suitable for a variety of applications. They are highly valued in electrochemical devices such as supercapacitors and rechargeable batteries (Wayu, M. 2021). These nanocomposites also contribute to environmental protection through efficient pollutant adsorption. Their role in catalysis boosts chemical reaction rates in industrial and lab-scale processes. Conductive materials improve their electron transfer ability. Biomedical applications include drug transport systems and imaging agents (Wan, S et al., 2016).

1.3 Lanthanide Doping in Nanocomposites

Lanthanides (rare earth elements) are increasingly used in nanocomposites due to their unique optical, magnetic and electronic properties. Lanthanide ions exhibit f-orbital electron transitions, making them ideal for luminescence and magnetism (Xie et al., 2022). Cerium nanocomposites are created by embedding cerium oxide (CeO_2) nanoparticles into a bulk matrix, allowing the material to exhibit enhanced properties. Cerium's ability to shift between +3 and +4 oxidation states provides these composites with redox-active capabilities, making them suitable for catalytic, biomedical and environmental uses. They also improve UV resistance, heat stability and structural integrity, making them valuable in numerous industrial applications. (Younis et al., 2016). Nanocomposites doped with erbium (Er^{3+}) ions exhibit a distinctive green photoluminescence, making them highly suitable for advanced technological applications. Erbium-based nanocomposites are widely used in optical amplifiers, lasers, upconversion for biomedical imaging and photovoltaic or optoelectronic devices due to their excellent energy transfer properties (Aquino et al.,2016).

The green synthesis of metal oxide and lanthanide-doped nanocomposites using plant extracts offers a sustainable and eco-friendly approach to nanoparticle fabrication. Plants have been effectively utilized for synthesizing various nanoparticles with significant antimicrobial, antioxidant and photocatalytic properties. The leaves of this medicinal plant, long valued in traditional healing practices, have recently gained attention for their role in green synthesis. Characterized by their compound structure and distinct aromatic scent when crushed, the leaves are rich in phytochemicals such as flavonoids, alkaloids, terpenoids, and essential oils. These natural compounds serve as efficient reducing and capping agents in the eco-friendly synthesis of metal nanoparticles (G Mamatha et al., 2021). This green approach eliminates the need for toxic chemicals, aligning with principles of sustainability and environmental safety. Moreover, the inherent biological properties of the leaves such as antimicrobial, antioxidant, and anti-inflammatory activities enhance the functional potential of the synthesized nanoparticles. Their strong antioxidant capacity also contributes to the stability and bioactivity of the nanomaterials. As a result, these plant-based extracts offer a sustainable and multifunctional platform for developing advanced materials in biomedical, environmental, and pharmaceutical applications (Aseen et al., 2025).

Widely distributed in tropical regions and deeply rooted in traditional Indian medicine, this medicinal plant has demonstrated strong potential in the green synthesis of nanoparticles. Its diverse phytoconstituents function as effective bioreducing and stabilizing agents, supporting the eco-conscious production of nanomaterials. The resulting nanoparticles often carry enhanced biological activity due to the plant's natural therapeutic compounds, offering considerable promise for application in biomedicine and pharmaceuticals (Saini et al.,2024). The stem and other parts of this medicinal plant are known for their therapeutic efficacy, largely due to the presence of alkaloids, glycosides, steroids, and polysaccharides. These compounds enable its use in green synthesis as effective reducing and capping agents. In addition to promoting nanoparticle formation, the plant imparts bioactivities such as antioxidant, anti-inflammatory, and anticancer effects, making the resulting nanomaterials highly relevant for clinical and pharmaceutical applications (Thakur,N et al., 2023). Used for centuries to address malaria-related fevers, diabetes, liver issues, and urinary infections, this plant's medicinal profile extends to modern green synthesis applications. Rich in immunostimulatory and detoxifying compounds, it acts as a natural catalyst in nanoparticle production. Its adaptogenic properties enhance the therapeutic relevance of the resulting nanomaterials, making it a valuable asset in integrated medical and nanoscience approaches (Arunachalam et al., 2022). This well-known medicinal plant from the Apocynaceae family is notable for its leaves, which are rich in pharmacologically important alkaloids such as vincristine and vinblastine. Traditionally used in

cancer therapy including for leukemia and Hodgkin's lymphoma its bioactive compounds are now also being explored for their role in green synthesis. These natural constituents serve as reducing and stabilizing agents in the eco-friendly production of nanoparticles, offering a dual benefit of therapeutic potential and sustainable nanomaterial development (Paarakh, M. P et al., 2019). The leaves of this traditional medicinal plant have long been used to treat diabetes, high blood pressure, and infections. They are packed with natural compounds that help lower blood sugar, fight germs, reduce inflammation, and boost the immune system. Today, these same compounds are being used in green synthesis, helping to create nanoparticles in an eco-friendly way. This makes the plant a key link between natural healing and modern medical technology (Mali, A. K et al., 2025).

2. Literature Review

(Prasanna et al,. 2019) Metal oxide-based nanomaterials are a fundamental class of materials from both a scientific and technological viewpoint. The methods for the manufacture of metal oxide-based nanomaterial as well as their characterization. In particular, we focus on the approaches for metal oxide particle synthesis using different physical and chemical synthetic approaches including growth mechanism, structure modulation, and production of metal oxides. The recent progress and advances in metal oxide-based polymeric nanocomposites, including their preparation using different techniques, has also been explored. Physical, rheological, conductive, optical and biological properties of the metal oxide based nanocomposites.

(Dharmalingam et al,. 2022) Innovative synthesis methods have emerged as powerful tools in materials science, offering dependable, sustainable, and environmentally benign routes for producing diverse nanomaterials such as metal/metal oxide nanoparticles, nanocomposites, and bio-inspired chemical structures. The synthesis process is pivotal, and a variety of significant protocols—including green synthesis techniques—have been reported, which are readily applicable in both academic and industrial contexts. This article reviews key synthetic strategies for metal oxide and sulfide-based nanocomposites and discusses their environmental applications, focusing on the photocatalytic degradation of organic dye contaminants. These nanocomposites are foundational materials in such applications and present expansive opportunities for future research.

(Ikim et al,. 2016) The preparation of In_2O_3 + CeO_2 and In_2O_3 + ZnO nanocomposites involves either mixing commercial nanopowders of the individual oxides or impregnating indium oxide nanoparticles with cerium or zinc salts, followed by their conversion to oxides. X-ray diffraction analysis confirms the presence of only two distinct phases: indium oxide and cerium or zinc

oxide, irrespective of the method used. Nanoparticle size and structure are characterized by transmission electron microscopy and XRD. Impregnation leads to the formation of small clusters of cerium or zinc oxides on the indium oxide nanoparticles' surface. The cerium oxide particles range from 3 to 15 nm, while zinc oxide particles range from 5 to 25 nm. An increase in oxide content slightly reduces particle sizes in the composites.

(Mamatha et al,. 2021) Antimicrobial cellulose nanocomposite films were developed through a three-step process using in situ synthesized silver and copper nanoparticles. The nanoparticles were generated using Vitex negundo leaf extract, which served as a green reducing and stabilizing agent. The cellulose films were fabricated via solution casting and infused with the plant extract through a swelling method. XRD analysis confirmed the presence of Ag and Cu nanoparticles embedded in the cellulose matrix. UV-Vis spectroscopy revealed absorption peaks at ~415 nm for Ag and ~570 nm for Cu, indicating successful bimetallic formation. SEM and EDAX analysis further confirmed the incorporation of Ag, Cu, and Ag-Cu particles, with average sizes of 60–74 nm. TGA and UTM tests demonstrated enhanced thermal stability and mechanical strength in bimetallic films compared to monometallic ones. These films exhibited strong antibacterial activity against both Gram-positive and Gram-negative bacteria. The visible color change in the films also supported the formation of bimetallic nanoparticles. Overall, the nanocomposite films show great promise for sustainable use in food, medical, and disinfectant packaging applications.

(M.V. Dass et al,. 2023) The increased use of medicinal plants has raised questions regarding their safety, efficacy, and utility. Since a result, a thorough understanding of plant phytochemical components is essential, since this information will be useful in the development of innovative therapeutic medications. Copper nanoparticles (CuNPs) have received a lot of interest due to their numerous applications. The physical and chemical features of CuNPs influence their uses. In the current study, CuNPs were synthesised utilising the chemical reduction process, with Tinospora cordifolia extract serving as a reducing agent due to their high phenolic and flavonoid content and their antibacterial and anti-inflammatory properties were also assessed. The majority of the absorption peaks found in the T. cordifolia leaves extract can also be found in the FT-IR spectrum of CuNPs, often at the same locations or with just little variations in the peak's location and intensity. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) found that the particles were generally spherical, with an average particle size of 15 to 70 nm. Their potential as anti-bacterial and antifungal drugs was demonstrated by the antimicrobial activity, they exhibited against S. aureus (18 mm), L. bacillus (22 mm), S. mutans (24 mm), and C. albicans (15 mm). Studies on the anti-inflammatory properties of biologically produced Cu NPs were determined.

(Udayabhanu et al,. 2015) The green synthesis of copper oxide nanoparticles (CuO Nps) by a solution combustion method using Tinospora cordifolia water extract. The Nps were characterized by XRD, SEM, TEM and UV–visible studies. XRD data indicates the formation of pure monoclinic crystallite structures of CuO Nps. SEM images show that the particles have sponge like structure with large surface area and the average crystallite sizes were found to be ~6–8 nm. These observations were confirmed by TEM analysis. Photocatalytic activity studies of CuO Nps reveal that they act as very good catalyst for the effective degradation of methylene blue (MB) in the presence of UV and Sun light. Also, the degradation of MB was found to be pH dependent. The Nps found to inhibit the activity of 1,1-Diphenyl-2-picrylhydrazyl (DPPH) free radicals effectively. CuO Nps exhibit significant bactericidal activity against Klebsiella aerogenes, Pseudomonas aeruginosa, Escherichia coli and Staphylococcus aureus. The study reveals a simple, ecofriendly and robust method for the synthesis of multifunctional CuO nanoparticle employing underutilized medicinal plants.

(Sonali et al,. 2023) Antibiotics have long been used to combat bacterial and fungal infections, but rising biofilm formation and multidrug resistance demand alternative solutions. This study explores the antimicrobial potential of silver nanoparticles synthesized using Catharanthus roseus leaf extract. UV–Vis spectroscopy confirmed nanoparticle formation with a peak at 392.4 nm. SEM and AFM analyses showed uniformly distributed, spherical nanoparticles sized between 20–30 nm, all under 100 nm. FTIR analysis indicated the presence of functional groups like phenols, alcohols, and alkenes. Zeta potential revealed a negative surface charge, and DLS recorded a polydispersity index of 0.290. Strong antibacterial activity was observed against Vibrio vulnificus, P. aeruginosa, and K. pneumoniae with inhibition zones of 21, 21, and 19 mm, respectively, and 33 mm against Candida albicans. Synergistic effects with ampicillin enhanced inhibition against S. aureus and E. coli. The nanoparticles exhibited hemocompatibility and antibiofilm activity, supporting their safety for in vivo use. Additionally, methyl orange degradation and bioinformatics studies highlighted environmental and drug discovery potential.

(Mustafa, Y.F., 2023) The rapid emergence of antibiotic-resistant pathogens has led to major public health concerns. In response, researchers are exploring alternatives to conventional antimicrobial drugs. Among these, nanotechnology has emerged as a particularly promising field. Antibacterial agents based on metal and metal oxide nanocomposites are effective because they bypass traditional bacterial resistance mechanisms and inhibit processes such as biofilm formation and other virulence factors. These nanocomposites penetrate bacterial cell walls and disrupt essential molecular functions. When combined with specific antibiotics, they may act synergistically to combat resistance. Furthermore, polymer-based nanocomposites offer

advantages like biodegradability and compatibility with biological systems, making them ideal for producing a range of medical and healthcare tools. Their integration into materials allows for broad antibacterial use, from surgical tools to antimicrobial textiles.

(Aliff et al,. 2020) Silver nanoparticles were green synthesized using Catharanthus roseus (C. roseus) dried bark extract and doped onto graphene oxide (AgNPs/GO) to form a porous nanocomposite. UV–Vis spectroscopy and XRD analysis confirmed the successful deposition of AgNPs onto GO sheets, with a characteristic absorption peak around 400 nm. TEM images revealed predominantly spherical AgNPs ranging from 1 to 26 nm in size. Functional groups like hydroxyl, epoxy, and carboxylic on GO contributed to the composite's anionic nature and facilitated nanoparticle attachment. AgNPs acted as spacers, preventing GO sheet restacking and increasing surface area. The adsorption capacity of the nanocomposite was tested against methylene blue (MB) dye. At 100 mM AgNPs concentration, nearly complete MB removal occurred within 5 minutes. Kinetic studies showed a pseudo second-order rate constant of 1.4563 $g\,mg^{-1}\,min^{-1}$. The enhanced adsorption performance was attributed to well-dispersed AgNPs and high surface porosity. This green-synthesized AgNPs/GO composite demonstrates promising potential for rapid environmental dye remediation.

(Tanuj et al., 2025) A green synthetic approach was used to prepare Cu-Ag co-doped ZnO nanocomposites (Cu-Ag-ZnO NCs) using Vitex negundo leaf extract as a bio-stabilizer. This study targets environmental pollutants like caffeine and Congo red, which often pollute water bodies due to industrial discharge. The nanocomposite exhibited crystalline ZnO peaks in XRD, with Cu and Ag incorporation confirmed, and particle size estimated at 35.23 nm. SEM images revealed a uniform, spherical morphology averaging 21.851 nm. Antimicrobial assays showed excellent activity, with MIC values significantly lower than standard drugs against S. aureus, E. coli, and A. niger. Under UV light, the NCs achieved rapid photocatalytic degradation: 95% of caffeine and 88% of Congo red in 25 minutes. Notably, the NCs retained high efficiency for up to seven cycles (caffeine) and six (Congo red). These findings highlight the dual utility of Cu-Ag-ZnO NCs for pollution control and antimicrobial defense. The approach exemplifies sustainable nanotechnology for real-world environmental applications.

2.1 Research Gap and Motivation

Many of researchers have studied about metallic nanocomposites and doped nanocomposites by green synthesis , but there are very liitle research on lanthanide doped nanocomposite by green synthesis. Further, there are less literature on the utilization of transition and lanthanides metals as dopants on nanocomposites. This work will give the comparative physical and chemical properties of green-synthesised, lanthanide doped metal oxide nanocomposite. Hence,

synthesized nanocomposits used for environment friendly anti- microbial, anti-oxidant and photocatalytic activities.

2.2 Objectives of the Study

1) To synthesize and characterize lanthanide doped transition metal oxide nanocomposites.
2) To assess their photocatalytic activity in degrading organic pollutants under UV/visible light.
3) To investigate their antimicrobial efficacy.

3. Proposed Methodology

3.1 Materials

Copper nitrate hexahydrate, Zinc nitrate hexahydrate, cobalt acetate tetrahydrate, Manganese nitrate hexahydrate, cerous chloride heptahydrate, Erbium nitrate hexahydrate, sodium hydroxide, and ethanol will be used as chemicals in synthesis. Plant leaves of Vitex Negundo, Tinospora Cardifolia, cantharanthus rosesus, will be collected from my home town of district Kangra, Himachal Pradesh.

3.2 Synthesis of plant extract

Plant leaves must be washed under tap water and then distilled water properly. After that crushed the leaver into the motar. Plant extract will be prepared by heating and crushing the leaves with Distilled water at 75 °C for 1 hour. After cooling the resulting solution, it will be filtered to obtain a clear solution. Then, the plant extract will be stored in a refrigerator for further experimentation. The same procedure has been followed for other leaf of plants.

3.3 Synthesis of Lanthanide-doped metal oxide nanocomposites

The microwave technique will be used for the synthesis of lanthanide doped metal oxide nanocomposites. The biosynthesis of lanthanide doped nanocomposites must be carried out using a simple microwave oven (2.45 GHz and 700 W). The equimolar solutions of transtation metal oxide will be mixed in different ratios to make a total volume of 300 ml. Add leaf extract into the mixture, and the pH value will be adjusted drop-wise with NaOH aqueous solution through a burette. The solution will be expose to microwave radiations in an oven for 10 min. The obtained precipitates shall be filter and wash with distilled water and ethanol and then dried at (80◦ to 90◦) C for 24 hours.

4. Characterization

The green synthesized lanthanide-doped transtition metal oxide NCs will be characterized by XRD to determine their crystallite size, crystal structure, lattice parameters, etc. The bandgap of synthesized nanoparticles will be measured with UV-Vis spectroscopy, and functional groups present inside the nanoparticles will be identified with Fourier transform infrared spectroscopy (FTIR). The particle size and Surface morphology will be determined with SEM, EDAX, TEM and XPS analysis.

4.1 Anti fungal activity assessment

The antifungal activity of transition metal and lanthanide doped transition metal nanocomposites must be evaluated against Fusarium, Ganoderma, by using the well diffusion method. To each Petri plate, which previously sterilized, containing the sterilized melted PDA medium, a separate concentration of Nanocomposite. The radial growth of fungal hyphae will be measured in all inoculated plates to determine the percentage of inhibition using the provided formula.

$$\text{Inhibition}(\%) = \text{T} - \text{C/T x } 100$$

For positive control, benzimidazole must included at same concentrations for comparison of Fusarium, Ganoderma fungi.

4.2 Antioxidant activity

The radical scavenging activity of lanthanide doped transtition metal oxide nanocomposites will assessed using the DPPH assay. Various concentrations of the synthesized catalyst must combined with DPPH solution in methanol. Upon the addition of nanoparticles, the violet color of the DPPH radical solution faded to colorless. After a specified incubation period, absorbance will be recorded, with ascorbic acid serving as the standard. A reduction in absorbance reflected an enhancement in DPPH radical-scavenging activity. The efficacy of scavenging DPPH free radicals will determined using the following equation.

$$\% \text{ inhibition} = \frac{(A0 - A1)}{A0} \times 100$$

Absorbance of the solution denoted by A1, while absorbance of the control solution denoted by A0.

Thesis Outline

The thesis will be comprised of following chapters:

Chapter 1 (Introduction): It will constitute of the brief account about lanthanide doped metal oxide nanocomposites and plant extract. It will also include the objectives of proposed study.

Chapter 2 (Literature Review): This chapter will deal with intense literature with context to the synthesis, characterization and applications green synthesis by lanthanide doped metal oxide nanocomposites. It will also include the research gap identification.

Chapter 3 (Materials and Methods): This chapter will comprise the detail of materials, chemical as well as green synthesis, characterization techniques and applications.

Chapter 4 (Results and Discussion): This chapter will include the reports regarding physical and chemical results along with the analysis and comparison of the findings the work.

Chapter 5 (Summary and Conclusion): It will include the overall summary and conclusion of the entire study with regard to the work with context to the objectives cited.

Chapter 6 (References): This will include references which will be strictly according to the havard style.

References:

Ahmaruzzaman, M., 2023. Metal oxides (ZnO, CuO and NiO)-based nanostructured materials for photocatalytic remediation of organic contaminants. Nanotechnology for Environmental Engineering, 8(1), pp.219–235.

Al-Saeedi, S.I., Al-Senani, G.M., Abd-Elkader, O.H. and Deraz, N.M., 2021. One pot synthesis, surface and magnetic properties of Cu_2O/Cu and Cu_2O/CuO nanocomposites. Crystals, 11(7), p.751.

Aquino, F.T., Ferrari, J.L., Maia, L.J.Q., Ribeiro, S.J.L., Ferrier, A., Goldner, P. and Gonçalves, R.R., 2016. Near infrared emission and multicolor tunability of enhanced upconversion emission from Er^{3+}–Yb^{3+} co-doped Nb_2O_5 nanocrystals embedded in silica-based nanocomposite and planar waveguides for photonics. Journal of Luminescence, 170, pp.431–443.

Arunachalam, K., Yang, X. and San, T.T., 2022. *Tinospora cordifolia* (Willd.) Miers: Protection mechanisms and strategies against oxidative stress-related diseases. Journal of Ethnopharmacology, 283, p.114540.

Asadpour, S., Kooravand, M. and Asfaram, A., 2022. A review on zinc oxide/poly(vinyl alcohol) nanocomposites: Synthesis, characterization and applications. Journal of Cleaner Production, 362, p.132297.

Aseen, A.H., Gowthami, V. and Jyolsna, P., 2025. Green synthesis of NiO/ZnO nanocomposite using *Vitex negundo* leaf extract for antibacterial and anti-inflammatory activities. Journal of Integrated Science and Technology, 13(3), p.1056.

Casati, R. and Vedani, M., 2014. Metal matrix composites reinforced by nanoparticles—a review. Metals, 4(1), pp.65–83.

Dharmalingam, P., Palani, G., Apsari, R., Kannan, K., Lakkaboyana, S.K., Venkateswarlu, K., Kumar, V. and Ali, Y., 2022. Synthesis of metal oxides/sulfides-based nanocomposites and their environmental applications: A review. Materials Today Sustainability, 20, p.100232.

Ikim, M.I., Yu Spiridonova, E., Belysheva, T.V., Gromov, V.F., Gerasimov, G.N. and Trakhtenberg, L.I., 2016. Structural properties of metal oxide nanocomposites: Effect of preparation method. Russian Journal of Physical Chemistry B, 10, pp.543-546.

Khan, S. and Hossain, M.K., 2022. Classification and properties of nanoparticles. In: Nanoparticle-based Polymer Composites. Woodhead Publishing, pp.15–54.

Li, X., Guo, Y., Li, Y. and Fu, R., 2022. Facile synthesis of Co_3O_4@G-C_3N_4 nanocomposites as catalysts for oxygen evolution reaction in alkaline electrolyte. Available at SSRN 4193501.

Mamatha, G., Sowmya, P., Madhuri, D., Mohan Babu, N., Suresh Kumar, D., Vijaya Charan, G. et al., 2021. Antimicrobial cellulose nanocomposite films with in situ generations of bimetallic (Ag and Cu) nanoparticles using *Vitex negundo* leaves extract. Journal of Inorganic and Organometallic Polymers and Materials, 31, pp.802–815.

Mali, A.K., Shivade, S.M., Vekhande, P.S., Pawar, T.T. and Dahale, K.G., 2025. *Catharanthus roseus*: A multipurpose plant with their morphology and dosage form. International Journal of Innovative Science and Research Technology, 10(4), pp.2554–2561.

Monteiro, B. and Simões, S., 2024. Recent advances in hybrid nanocomposites for aerospace applications. Metals, 14(11), p.1283.

Mustafa, Y.F., 2023. Modern developments in the application and function of metal/metal oxide nanocomposite–based antibacterial agents. BioNanoScience, 13(2), pp.840–852.

Nethravathi, P.C., Kumar, M.P., Suresh, D., Lingaraju, K., Rajanaika, H., Nagabhushana, H. and Sharma, S.C., 2015. Tinospora cordifolia mediated facile green synthesis of cupric oxide nanoparticles and their photocatalytic, antioxidant and antibacterial properties. Materials Science in Semiconductor Processing, 33, pp.81–88.

Pacheco, I. and Buzea, C., 2020. Nanomaterials and nanocomposites: Classification and toxicity. In: Handbook of Nanomaterials and Nanocomposites for Energy and Environmental Applications, pp.1–38.

Paarakh, M.P., Swathi, S., Taj, T., Tejashwini, V. and Tejashwini, B., 2019. *Catharanthus roseus* Linn—a review. Acta Scientific Pharmaceutical Sciences, 3(10), pp.19–24.

Prakash, M.D., Sampath, S., Amudha, K., Nadeem, A., Lopes, B.S., Durga, B. and Muthupandian, S., 2023. Eco-friendly green synthesis of copper nanoparticles from *Tinospora cordifolia* leaves: Optical properties with biological evaluation of anti-microbial, anti-inflammatory and anti-oxidant applications. Materials Technology, 38(1), p.2247908.

Prasanna, S.S., Balaji, K., Pandey, S. and Rana, S., 2019. Metal oxide based nanomaterials and their polymer nanocomposites. In Nanomaterials and polymer nanocomposites (pp. 123-144). Elsevier.

Priyadarshini, S. and Pati, S., 2023. Green synthesis of silver nanoparticles from Catharanthus roseus and its antibacterial properties. Applied Nanoscience, 13(9), pp.6281–6298.

Rohaizad, A., Shahabuddin, S., Shahid, M.M., Rashid, N.M., Hir, Z.A.M., Ramly, M.M. et al., 2020. Green synthesis of silver nanoparticles from *Catharanthus roseus* dried bark extract deposited on graphene oxide for effective adsorption of methylene blue dye. Journal of Environmental Chemical Engineering, 8(4), p.103955.

Saini, R., Mishra, R.K. and Kumar, P., 2024. Green synthesis of reduced graphene oxide using the *Tinospora cordifolia* plant extract: Exploring its potential for methylene blue dye degradation and antibacterial activity. ACS Omega, 9(18), pp.20304–20321.

Tanuj, Sharma, A., Kumar, R., Kumar, S. and Kalra, N., 2025. Unleashing the potential of *Vitex negundo* leaves: Innovative fabrication of Cu–Ag–ZnO nanocomposite for enhanced photocatalytic degradation of caffeine and Congo red dye coupled with antimicrobial efficacy. Biomass Conversion and Biorefinery, pp.1–18.

Thakur, N. and Thakur, N., 2023. Removal of organic dyes and free radical assay by encapsulating polyvinylpyrrolidone and Tinospora cordifolia in dual (Co–Cu) doped TiO_2 nanoparticles. Environmental Pollution, 335, p.122229.

Wan, S., He, F., Wu, J., Wan, W., Gu, Y. and Gao, B., 2016. Rapid and highly selective removal of lead from water using grapheme oxide-hydrated manganese oxide nanocomposites. Journal of Hazardous Materials, 314, pp.32–40.

Wayu, M., 2021. Manganese oxide carbon-based nanocomposite in energy storage applications. Solids, 2(2), pp.232–248.

Xie, Y., Song, Y., Sun, G., Hu, P., Bednarkiewicz, A. and Sun, L., 2022. Lanthanide-doped heterostructured nanocomposites toward advanced optical anti-counterfeiting and information storage. Light: Science & Applications, 11(1), p.150.

Younis, A., Chu, D. and Li, S., 2016. Cerium oxide nanostructures and their applications. Functional Nanomaterials, 3, pp.53–68.

CERTIFICATE

(SYNOPSIS APPROVAL CERTIFICATE)

This is to certify that the Synopsis/Revised Synopsis for Ph.D. Thesis titled, "**A Study of Lanthanide-Doped Metal Oxide Nanocomposites for Photocatalytic and Biomedical Applications via Green Synthesis**", submitted by Miss. Kaajal to the Career Point University, Hamirpur (H.P.), India in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the Division/Department of Physics, School of Basic and Applied Sciences has been approved by the Research Advisory Committee (RAC) after an Oral Examination of the student on dated 15/05/2025

26/05/25

Dr. Naveen Thakur
Professor
(Supervisor)

Research Advisory Committee

Dr. Rajender Kumar,
Associate Professor,
Department of Physics,
CPU, Hamirpur (H.P.)
(RAC Member)

26.05.2025

Dr. Kuldeep Kumar,
Associate Professor,
Department of Chemistry,
CPU, Hamirpur (H.P.)
(RAC Member)

26/05/25

Dr. Neha
AssistantProfessor,
DivisionofZoology,
CPU, Hamirpur (H.P)
(RAC Member)

Dr. Rajender Kumar, Associate Professor, CPU, Hamirpur (H.P.)
(Head) Department of Physics

26.05.2025

Dr. Kuldeep Kumar, Associate Professor, CPU, Hamirpur (H.P.)
(Dean PG Studies-cum-Director Research)

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